HW 20 All Things Fluids

1) Iron Man decides to take his steel ($\rho = 7.8 \times 10^3 kg/m^3$) raft for a float in a lake of mercury ($\rho = 13.6 \times 10^3 kg/m^3$). If his mass is 130.0 kg and his raft is $2m \times 2m \times 0.5m$, how deep will his raft be in the mercury?

The weight of the raft plus the weight of the man must equal the weight of the mercury displaced.

$$Volume_{raft} = 2m(2m)(0.5m)$$

$$m_{raft} = Volume(\rho)$$

$$m_{raft} = (2m^3)(7.8 \times 10^3 kg/m^3)$$

$$m_{raft} = 15600kg$$

$$m_{raft\,system} = m_{raft} + m_{man}$$

$$m_{raft\,system} = 15600kg + 130kg$$

$$m_{raft\,system} = 15730kg$$

$$W_{mercury} = W_{raft\,system}$$

$$m_{mercury}g = m_{raft\,system}g$$

$$m_{mercury} = m_{raft\,system}$$

$$m_{mercury} = 15730kg$$

$$Volume = \frac{m}{\rho}$$

$$Volume = \frac{15730kg}{(13600kg/m^3)}$$

$$Volume = 1.16m^3$$

$$Depth = \frac{1.16m^3}{(4m)^2}$$

$$Depth = \boxed{0.289m}$$

2. A patient is to be given a blood transfusion. The blood is to flow though a tube from a raised bottle to a needle inserted in the vein. The diameter of the needle is 0.8 mm and the required flow rate is $2.0cm^3$ of blood per minute. How high should the bottle of blood be placed above the needle? ($\rho_{blood} = 1.05E3kg/m^3$) The blood pressure in the vein is 110,400 Pa.

$$A = \pi r^2$$

$$A = \pi(0.0004m)^2$$

$$v = \frac{Q}{A}$$

$$v = \frac{3.33 \times 10^{-8} m^3/s}{5.03 \times 10^{-7} m^2}$$

$$P + \frac{1}{2}\rho v^2 + \rho g \triangle y = P + \frac{1}{2}\rho v^2 + \rho g \triangle y$$

$$\rho g \triangle y = \frac{1}{2}\rho v^2 + P_g$$

$$(1050kg/m^3)(9.8m/s^2)\triangle y = \frac{1}{2}(1050kg/m^3)(0.0662m/s)^2 + (110400Pa - 101000Pa)$$

$$\triangle y = \boxed{0.914m}$$

3. A tub of water rests on a scale as shown below. The weight of the tub plus water is 100 N. A 50 N concrete brick is then lowered down from a fixed arm into the water but does not touch the tub. What does a scale placed under the tub read?

$$W_{brick} = mg$$

$$50N = (9.8m/s)m$$

$$m = 5.10kg$$

$$Volume = \frac{m}{\rho}$$

$$Volume = \frac{5.10kg}{2300kg/m^3}$$

$$Volume = 0.00222m^3$$

$F_b = (0.00222m^3)(1000kg/m^3)(9.8m/s^2) = 21.7N$

The water pushes up on the block with this force. Thus, as the block pushes the water with an equal and opposite force, the 100N weight of the system is increased by that amount. The scale reads $\boxed{122N}$

4. A fire hose sprays water 16 meters into the air. If the diameter of the nozzle is 2.2cm and the diameter of the hose is 6.35cm how much pressure is the water under as it travels through the hose?

$$v^2 = v_o^2 + 2g\triangle y$$

$$0 = v_o^2 + 2(-9.8m/s)(16m)$$

$$v_o = \sqrt{2 \cdot 9.8m/s \cdot 16m} = 17.7m/s$$

$$A = 0.011^2 \pi m^2$$

$$Q = (3.8 \times 10^{-4}m^2)(17.7m/s) = 0.00673m^3/s$$

$$v_1 = \frac{0.00673m^3/s}{0.00317m^2} = 2.12m/s$$

$$P_1 + \frac{1}{2}\rho v_1^2 = P_o + \frac{1}{2}\rho v_o^2$$

$$P_1 + \frac{1}{2}(1000kg/m^3)(2.12m/s)^2 = 101000Pa + \frac{1}{2}(1000kg/m^3)(17.7m/s)^2$$

$$P_1 = \boxed{255,562.9Pa}$$

5. A 0.10-kilogram solid rubber ball is attached to the end of an 0.80 meter length of light thread. The ball is swung in a vertical circle, as shown in the diagram above. Point P, the lowest point of the circle, is 0.20 meter above the floor. The speed of the ball at the top of the circle is 6.0 meters per second, and the total energy of the ball is kept constant.

a. Determine the total energy of the ball, using the floor as the zero point for gravitational potential energy.

$$Total\ Energy = U_g + K_E$$

$$Total\ Energy = mg \cdot d + \frac{1}{2}mv^2$$

$$Total\ Energy = 0.1kg(9.8m/s^2)(1.6m) + \frac{1}{2}(0.1kg)(6m/s)^2$$

$$Total\ Energy = \boxed{3.564J}$$

b. Determine the speed of the ball at point P, the lowest point of the circle.

$$\boxed{COE}$$

$$3.564J = U_g + K_E$$

$$3.564J = mg \cdot d + \frac{1}{2}mv^2$$

$$3.564J = (0.1kg)(9.8m/s^2)(0.2m) + \frac{1}{2}(0.1kg)v^2$$

$$v = \boxed{8.21m/s}$$

c. Determine the tension in the thread at

i. the top of the circle;

$$\sum F = ma$$

$$-T - W = -m(\frac{v^2}{r})$$

$$T + W = m(\frac{v^2}{r})$$

$$T + 0.1kg(9.8m/s^2) = 0.1kg(\frac{(6m/s)^2}{0.8m})$$

$$T = \boxed{3.52N}$$

ii. the bottom of the circle.

$$\sum F = ma$$

$$T - W = m(\frac{v^2}{r})$$

$$T - 0.1kg(9.8m/s^2) = 0.1kg(\frac{(8.21m/s)^2}{0.8m})$$

$T = \boxed{7.44N}$

The ball only reaches the top of the circle once before the thread breaks when the ball is at the lowest point of the circle.

d. Determine the horizontal distance that the ball travels before hitting the floor.

$$\triangle x = v_o t + \frac{1}{2}at^2$$

$$-0.2m = \frac{1}{2}(9.8m/s^2)t^2$$

$$t = 0.202sec$$

$$8.21m/s(0.202sec) = \boxed{1.66m}$$